

In situ characterization of plum landraces originated from the region of western Serbia

I. Glišić^{1,a}, N. Milošević¹, J. Tomić¹, M. Milinković², M. Đorđević¹, S. Marić¹, S. Radičević¹ and B. Popović¹

¹Fruit Research Institute, Čačak, Republic of Serbia; ²Institute of Soil Science, Republic of Serbia.

Abstract

Eleven plum landraces ('G-1' to 'G-11') of unknown origin were segregated and analyzed as single trees in orchards of the western Serbia region during 2020/21. The investigation included the most important agronomic traits such as harvest date, fruit and stone weight, fruit dimensions, surface area, soluble solids and total acids as well as the ratio between these two properties, total phenols and total anthocyanins, antioxidant activity and field resistance to Sharka disease (*plum pox virus*). The collected material showed a wide range of variability within the studied properties. The investigated plum genotypes ripened between the July 30 ('G-1') and September 15 ('G-11'). The 'G-3' was characterized by the largest fruit (37.12 g), while the smallest fruit was found in 'G-4' and 'G-5' (11.76 g; 13.39 g). In terms of the fruit chemical composition, the best results were obtained in 'G-5' and 'G-11' which were characterized by the highest content of soluble solids (20.45%; 21.10%) and ratio between soluble solids and total acids (21.73; 30.14). The smallest content of soluble solids (14.25%) was found in 'G-9', while 'G-3' and 'G-4' had the smallest ratio between soluble solids and total acids (8.53; 9.59) due to the high value of total acids (1.94%; 2.09%). The genotype 'G-2' was characterized by the highest content of total phenols (197.50 mg GAE 100 g⁻¹ FW) and antioxidant activity (63.26%), while the value of total anthocyanins was the highest in 'G-5' and 'G-8' (17.32 and 18.93 mg C3G 100 g⁻¹ FW, respectively). The lowest level of bioactive compounds was found in 'G-3'. Regarding the field resistance to Sharka disease, the assessed genotypes can be divided into three groups: without symptoms ('G-2' to 'G-4', 'G-6' and 'G-7'), with minor symptoms ('G-1', 'G-8' and 'G-9') and with moderate symptoms ('G-5', 'G-10' and 'G-11').

Keywords: *Prunus domestica* L., ripening time, fruit properties, sharka resistance

INTRODUCTION

Increased genetic erosion of various crops caused by land use change, promotion and cultivation of new commercial genotypes of high productivity has been present in recent times. With the limited gene pool, the negative effects of climate change are becoming more and more pronounced, and the appearance of new diseases and pests is also being observed (Pérez et al., 2022). Problems caused by climate change have also come to be important for plum production. Thus, Neumüller et al. (2021) reported that in the past 20 years, previously unknown or rarely observed problems such as winter and spring frost damages, heat damage in flesh, double fruits, increased June fruit drop are becoming more and more apparent in the orchard and pose new challenges for breeders. As is known, crop diversity ensures the resilience and adaptive capacity of agricultural systems (Renard and Tilman, 2019). Namely, landraces arose as a result of selection by farmers, as well as spontaneous exchange and gene flow, while their continuous cultivation led to local adaptation (Camacho Villa et al., 2005; Cleveland and Soleri, 2007; Khoury et al., 2022). Thus conservation of crop genetic resources is of fundamental importance for developing new cultivars adapted to changing climate conditions and with better fruit quality (Pérez et al., 2022).

The Balkan Peninsula is one of the regions that is characterized by valuable plum

^aE-mail: iglisic@institut-cacak.org

genetic material (Ternjak et al., 2023). The results of previous studies indicate the existence of numerous synonyms and mislabeling in different collections, which imposes the need for further genotypic and phenotypic characterization of plum germplasm (Gaši et al., 2020). Such a study was conducted in Croatia and included, among other things, 42 traditional Croatian accessions that were assessed using microsatellite markers and distinctness, uniformity, and stability plum descriptors (Kazija et al., 2014). The results of this study indicate that traditional Croatian accessions represent a diverse and underutilized plant genetic material. Likewise, plum landraces in Serbia are numerous, heterogeneous and well adapted to existing agro-ecological conditions (Milošević and Milošević, 2012). Mišić (2002) indicates some plum genotypes of local importance as potential gene donors for late flowering and ripening time, resistance to drought and high temperatures while Paunovic and Paunovic (1994) point out their resistance to economically important diseases. Apart from this, the fruits of local plum genotypes often show exceptional nutritional properties, especially in terms of total phenol content and antioxidant capacity, as well as in terms of mineral and pectin content (Rop et al., 2009; Tomić et al., 2019).

The Fruit Research Institute has a long tradition of in situ and ex situ collection of plum genotypes (Ogašanić et al., 1996, Milenković et al., 2006; Glišić and Milošević, 2015; Milošević et al., 2017; Glišić et al., 2018; Tomić et al., 2019), thus ensuring the preservation of genetic basis for breeding activities and development of new selections and cultivars that can be interesting for commercial growing, as well as developing of new rootstocks for plum, peach and apricot (Milošević et al., 2010). Therefore, this work was aimed primarily to study harvest date, physical fruit traits and nutritional value, as well as field resistance to Sharka disease (*plum pox virus*) in 11 in situ plum landraces grown in different regions of western Serbia.

MATERIALS AND METHODS

Plant material

Eleven plum landraces (Table 1) of unknown origin were sampled as single trees and analyzed in orchards of growers in the region of western Serbia during 2020/21. More precisely, three genotypes each in the region of Kraljevo ('G-2' to 'G-4'), Užice ('G-6', 'G-7', 'G-11') and Gornji Milanovac ('G-8' to 'G-10'), and two genotypes in the region of Čačak ('G-1' and 'G-5').

Table 1. Location and condition of tree of the assessed plum landraces.

Genotype	Location		
	Latitude	Longitude	Altitude (m)
G-1	43°57'439"N	20°19'285"E	358.00
G-2	43°49'425"N	20°53'538"E	509.00
G-3	43°49'423"N	20°53'544"E	507.00
G-4	43°49'436"N	20°53'521"E	512.00
G-5	43°86'149"N	20°42'354"E	207.00
G-6	43°54'595"N	19°52'210"E	539.00
G-7	43°54'675"N	19°52'297"E	555.5
G-8	44°09'304"N	20°40'967"E	443.00
G-9	44°09'090"N	20°24'009"E	642.00
G-10	44°05'015"N	20°50'667"E	405.00
G-11	43°54'738"N	19°52'306"E	539.00

Phenological characteristics

Ripening time was determined as a date when the most of the fruits were ripe for consumption and had typical taste and firmness (BBCH stage 89, Meier 2018).

Pomological characteristics

Fruit and stone weight were measured by technical scale Adventurer Pro AV812M (Ohaus Corporation, Switzerland) and expressed in grams (g). The digital calliper (Kronen, Germany) was used for determination of fruit dimensions (height, width and thickness), whereas mean geometrical diameter was calculated according to formula $[(\text{fruit height} \times \text{fruit width} \times \text{fruit thickness})^{1/3}]$ given by Mohsenin (1986). According to recommendation of cited author, also, the fruit surface area was calculated $[(\text{mean geometrical diameter})^2 \times \pi]$. All investigated dimensions of fruit as well as fruit surface area were expressed in mm and mm², respectively. The content of soluble solids (%) was measured by portable refractometer (Hanna Instruments, Germany), while the content of total acids expressed as malic acid (%) was determined by titration with 0.1 N NaOH up to pH 8.1 in the presence phenolphthalein as an indicator. The ratio between contents of soluble solids and total acids was calculated. The Folin-Ciocalteu method (Singleton and Rossi, 1965) was used for determination of total phenol content on the Spectrophotometer (Jenway 6300, United Kingdom) and expressed in gallic acid equivalents per 100 g of fresh weight (mg GAE 100 g⁻¹ FW). The antioxidant activity (expressed as % inhibition of the DPPH radical) was determined using DPPH (2,2-diphenyl-1-picrylhydrazyl) assay reported by Sánchez-Moreno et al. (1998). The total anthocyanin content, expressed in mg of cyanidin-3-glucoside per 100 g of fresh weight (mg C3G 100 g⁻¹ FW), was determined by the pH differential method.

Disease susceptibility

The field resistance to causal agents of Sharka disease (*plum pox virus*), displayed on the scale from 1 to 9, was determined by frequency and intensity of symptoms on leaves and fruits in natural conditions of infections according to methodology given by IBPGR (1984) and Glišić et al. (2016).

Statistical analysis

The variance analysis (ANOVA) was used for establishing the significance of differences between genotypes regarding all investigated parameters except soluble solids and total acids content and the ratio between them. In the cases when the *F* test indicated significant differences, testing of arithmetic means was further carried out using the test of least significant differences (LSD test) for significance threshold of $P \leq 0.05$. Data analysis was performed using the SPSS statistical software package, Version 8.0 for Windows (SPSS, Inc., Chicago, IL).

RESULTS AND DISCUSSION

Fruits of investigated plum genotypes were harvested between July 30 and September 15 (Table 2). Taking into account the classification of plum cultivars according to the ripening time given by Milatović (2019), genotypes 'G-1' to 'G-4' can be characterized as medium early, genotypes 'G-5' to 'G-9' as medium late and genotypes 'G-10' and 'G-11' as very late.

Table 2. Fruit and stone weight and ripening time of the assessed plum landraces.

Genotype	Fruit weight (g)	Stone weight (g)	Ripening time (date)
G-1	17.24±0.78 de*	1.08±0.18 b	30 July
G-2	20.82±0.90 bc	1.11±0.18 b	30 July
G-3	37.13±1.12 a	2.39±0.41 a	31 July
G-4	11.76±0.53 g	0.57±0.07 d	1 August
G-5	13.39±1.66 fg	0.85±0.04 bcd	10 August
G-6	20.34±1.33 bc	0.82±0.16 bcd	11 August
G-7	21.43±1.28 b	0.92±0.04 bc	11 August
G-8	15.47±1.66 ef	0.66±0.03 cd	12 August
G-9	21.50±1.56 b	0.94±0.15 bc	12 August
G-10	18.58±1.15 cd	0.85±0.05 bcd	13 September
G-11	20.16±2.84 bc	0.90±0.18 bc	15 September

Different lower-case letters within columns indicate significant differences for $P \leq 0.05$ (LSD test).

Depending on genotype, fruit weight varied from 11.76 g ('G-4') to 37.13 g ('G-3') (Table 2). According to the scale for fruit size obtained by Milatović (2023), 'G-1', 'G-4', 'G-5', 'G-8' and 'G-10' belong to the group of small fruit genotypes; 'G-2', 'G-6', 'G-7', 'G-9' and 'G-11' are genotypes of medium-large fruit, whereas 'G-3' is genotype of large fruit. Stone of the most studied plum genotypes was small with the exception of 'G-1' and 'G-2', as well as 'G-3' whose stones were medium large and large, respectively.

The assessed plum genotypes differed significantly in terms of fruit dimensions, mean geometric fruit diameter and fruit surface area (Table 3). The highest fruit height (40.94 mm), width (36.39 mm) and thickness (38.68 mm), as well as mean geometrical diameter (38.68 mm) and fruit surface area (4702.02 mm²) were determined in 'G-3'. The lowest fruit height, mean geometrical diameter and fruit surface area were found in 'G-5' (29.16, 26.68, 2237.32 mm², respectively), while 'G-4' was characterized by the smallest fruit width (24.42 mm) and 'G-8' by the smallest fruit thickness (19.18 mm).

Table 3. Fruit dimensions (height, width and thickness), mean geometrical diameter of fruit and fruit surface area of the assessed plum landraces.

Genotype	Fruit height (mm)	Fruit width (mm)	Fruit thickness (mm)	Mean geometrical diameter (mm)	Fruit surface area (mm ²)
G-1	34.75±1.23 c	27.29±0.82 c	29.02±0.17 b	30.19±0.44 d	2863.76±83.65 c
G-2	38.83±1.89 b	28.47±0.86 b	30.46±0.52 b	32.35±0.84 bc	3289.9±171.21 b
G-3	40.94±0.32 a	36.39±0.49 a	38.86±0.56 a	38.68±0.25 a	4702.02±61.78 a
G-4	32.55±0.97 d	24.42±0.55 f	24.72±1.25 bc	26.98±0.88 f	3211.26±76.16 b
G-5	29.16±0.87 e	25.18±0.68 ef	25.76±0.70 bc	26.68±0.71 f	2237.32±118.65 e
G-6	32.08±0.52 d	25.56±0.96 e	26.01±1.02 bc	27.47±0.77 f	2673.05±483.05 cd
G-7	30.45±0.53 e	26.09±1.05 d	26.12±0.72 b	27.70±0.71 ef	2411.58±125.5 de
G-8	32.74±1.66 c	26.42±0.38 d	19.18±0.69 c	28.76±0.53 e	2599.15±94.95 cd
G-9	39.93±0.87 ab	28.94±0.69 b	31.97±0.70 ab	33.31±0.63 b	3485.91±132.95 b
G-10	38.92±0.15 b	28.98±0.82 ab	28.08±0.38 b	31.63±0.39 c	3211.26±76.16 b
G-11	39.98±1.07 ab	29.02±1.73 ab	29.06±1.45 b	32.30±1.40 c	3282.41±1.73 b

Different lower-case letters within columns indicates significant differences for $P \leq 0.05$ (LSD test).

Consumers acceptance of fruit is highly dependent on fruit taste, which is closely related to soluble solids content (Tulipani et al., 2008), total acids content (Lee, 1993; Silva et al., 2002) and the ratio between them (Crisosto et al., 2004). The soluble solids content of assessed plum landraces was ranged between 14.25% ('G-9') and 24.55% ('G-5'), while content of total acids varied from 0.70% ('G-10' and 'G-11') to 2.09% ('G-4') (Table 4). The lowest value of soluble solids and total acids ratio was determined in 'G-3' (8.53) and the highest in 'G-11' (30.14). Given that soluble solids content over 12% (Crisosto et al., 2004, 2007; Neumüller, 2011) and soluble solids and total acids content ratio over 10 (Vangdal et al., 2007) are thresholds for acceptability by consumers, our results suggest that all investigated genotypes except 'G-3' and 'G-4' meet this criterion.

Phenolic compounds include natural secondary metabolites that determine the color, appearance, flavor, and health-promoting properties of fruit (Lattanzio, 2003). Anthocyanins, accumulated predominately in the fruit skin, contribute to human health due to their antioxidant, anticarcinogenic, antimutagenic, antimicrobial, anti-inflammatory, and neuroprotective properties (Salehi et al., 2020). Different antioxidant components in plum fruit (phenols, flavonoids and anthocyanins) contribute to the total antioxidant activity (Trendafilova et al., 2022) (Table 5). Results obtained in our study showed a positive correlation between phenol content and antioxidant activity. Thus genotype 'G-3' was characterized by the lowest total phenol content and antioxidant activity (71.33 mg GAE 100 g⁻¹ FW, 29.54%, respectively), while in 'G-2' the highest values of mentioned parameters

were found (197.50mg GAE 100 g⁻¹ FW, 63.26%, respectively). In genotype 'G-3' no anthocyanin was found, while the highest total anthocyanin content was identified in genotype 'G-8' (18.93 mg C3G 100 g⁻¹ fruit weight). The mentioned results are expected considering the fact that content of anthocyanins correlates with the intensity of the fruit skin color (Vizzotto et al., 2006). Namely, genotype 'G-3' is characterized by the yellow and genotype 'G-8' by the dark blue to black color of fruit skin (data not presented). Obtained values of bioactive compounds content in the fruit of the assessed plum landraces in our study were in agreement with the results published by Tomić et al. (2019) and Trendafilova et al. (2022), while Rop et al. (2009) reported higher values of the tested parameters in commercial and local plum genotypes grown in the locality of the White Carpathian Mountains.

Table 4. Fruit chemical composition of the assessed plum landraces.

Genotype	Soluble solids content (%)	Total acids content (%)	Soluble solids/total acids
G-1	19.50	1.11	17.58
G-2	16.60	1.35	12.29
G-3	16.55	1.94	8.53
G-4	20.05	2.09	9.59
G-5	24.55	1.13	21.73
G-6	20.45	1.29	15.85
G-7	18.25	1.12	16.29
G-8	15.65	1.17	13.89
G-9	14.25	1.13	12.61
G-10	16.10	0.70	23.00
G-11	21.10	0.70	30.14

Table 5. Content of bioactive compounds in the fruit of the assessed plum landraces.

Genotype	Total phenol content (mg GAE 100 g ⁻¹ fruit weight)	Antioxidant activity (%)	Total anthocyanin content (mg C3G 100 g ⁻¹ fruit weight)
G-1	104.50±7.50 e	35.81±4.97 c	9.18±1.26 b
G-2	197.50±9.50 a	63.26±3.17 a	7.51±0.41 bcd
G-3	71.33±6.51 ef	29.54±0.58 c	0.00±0.00 f
G-4	85.00±4.00 ef	30.76±1.65 c	5.42±0.42 bcd
G-5	184.50±12.50 ab	57.78±0.29 ab	17.32±0.20 a
G-6	94.08±2.00 ef	31.56±1.15 c	7.51±0.56 bcd
G-7	166±30.00 b	36.31±3.32 c	3.13±0.63 ef
G-8	181.50±12.50 ab	60.30±4.39 a	18.93±6.01 a
G-9	108.00±3.00 de	36.09±4.25 c	8.35±4.59 bc
G-10	129.00±27.00 cd	49.85±15.27 bc	4.18±0.84 de
G-11	136.5±0.50 c	60.73±5.83 a	4.80±1.04 cd

Different lower-case letters within columns indicates significant differences for $P \leq 0.05$ (LSD test).

The most dangerous and economically the most important disease of plum trees is Sharka (Glišić et al., 2016; Cambra et al., 2006). Consequently, resistance to this disease has a top priority among plum breeding goals (Neumüller et al., 2021; Milošević et al., 2021) so it is of great importance to monitor the existing germplasm and select resistant genotypes that would have potential for use in breeding.

Under natural conditions of infections no symptoms of Sharka were found in genotypes 'G-2' to 'G-4', 'G-6' and 'G-7' (Figure 1). Landraces 'G-1', 'G-8' and 'G-9' showed mild symptoms on the leaves, while 'G-5', 'G-10' and 'G-11' showed symptoms in both the leaf and the fruit, but without premature fruit drop.

CONCLUSIONS

The results of this study indicate a great variability of the tested properties among the studied Serbian plum landraces, which represent an outstanding genetic basis and the source of germplasm for further research and breeding work. In order to clarify the genotypic and environmental effects, genetic identification of the collected accessions is planned in the coming years. Also, future investigations of the collected genotypes in field and laboratory conditions should be extended to a larger number of significant properties and provide answers about the possibilities of their use for the development of new varieties and substrates or the introduction into commercial production of plums intended for fresh consumption, drying and processing into alcoholic beverages or other products.

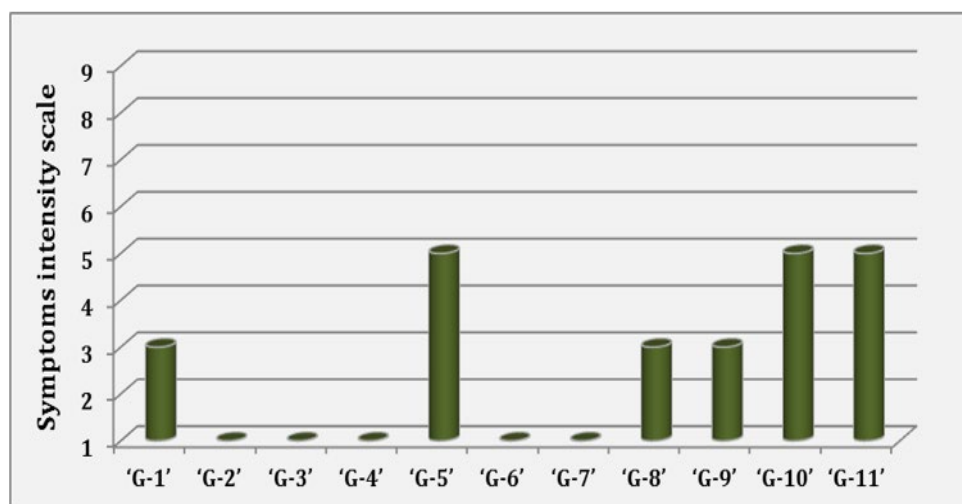


Figure 1. Reaction of the assessed plum landraces on PPV (*plum pox virus*) in natural conditions of infection. Symptom intensity scale (1-9): 1 – no symptoms, 3 – minor symptoms, 5 – moderate symptoms, 7 – strong symptoms, 9 – very strong symptoms.

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